Claims

WHAT IS CLAIMED IS:

1. A method for reducing speckle in an ultrasonic image formed from a digitized scan line including a plurality of linearly arranged signal intensity data points obtained from ultrasonic energy reflected by structures within a body, said method comprising the steps of:

dividing the scan line into a plurality of intensity pixels, each of said intensity pixels including at least one data point of said plurality of signal intensity data points;

determining a raw intensity level for each of said plurality of intensity pixels;

determining a feature gain factor for each pixel of said plurality of intensity pixels;

calculating a corrected intensity level for each of said plurality of intensity pixels by multiplying the raw intensity level for each intensity pixel by the feature gain factor for the corresponding intensity pixel; and

displaying the corrected intensity level of each of said plurality of intensity pixels.

2. A method as set forth in claim 1 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels comprises:

rectifying a signal intensity obtained for each data point within the respective intensity pixel; and

calculating an average of the rectified signal intensities of the data points within the intensity pixel.

3. A method as set forth in claim 2 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels further comprises compressing the calculated average of the rectified signal intensities for the intensity pixel.

4. A method as set forth in claim 3 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels comprises

logarithmically compressing the calculated average of the rectified signal intensities for the intensity pixel.

5. A method as set forth in claim 1 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels is repeated over time to provide a digitized intensity level waveform for each of said intensity pixels, and the step of determining the feature gain factor for each pixel of said plurality of intensity pixels comprises:

selecting a feature detection pixel corresponding to each intensity pixel of said plurality of intensity pixels;

rectifying the intensity level waveform for each of said feature detection pixels;

performing a Fourier analysis on the rectified intensity level waveform to obtain Fourier coefficient amplitudes for each of the feature detection pixels; and

computing a power spectrum from the Fourier coefficient amplitudes for each of the feature detection pixels.

6. A method as set forth in claim 5 wherein the step of determining the feature gain factor for each pixel of said plurality of intensity pixels comprises:

calculating a cluster index for the feature detection pixel corresponding to the intensity pixel; and

selecting a feature gain factor for each intensity pixel based at least in part upon the cluster index calculated for the feature detection pixel corresponding to the respective intensity pixel.

7. A method as set forth in claim 6 wherein the step of calculating the cluster index for each feature detection pixel comprises:

determining a value of a peak power spectrum for the plurality of feature detection pixels; and

dividing the power spectrum computed for each feature detection pixel by the value of the peak power spectrum for the plurality of feature detection pixels.

8. A method as forth in claim 5 wherein the digitized scan line is a first scan line of a plurality of digitized scan lines, and the step of determining the raw intensity level for each of said plurality of intensity pixels comprises:

calculating an initial intensity level for each of said plurality of intensity pixels; and

averaging the initial intensity level of each intensity pixel and the initial intensity level of an adjacent intensity pixel.

9. A method as set forth in claim 1 wherein each intensity pixel includes about 32 adjacent signal intensity data points.

10. A method as set forth in claim 9 wherein each of feature detection pixel includes about 64 adjacent signal intensity data points.

11. A method as set forth in claim 10 wherein each intensity pixel and the corresponding feature detection pixel share a central pair of signal intensity data points.

12. A method as set forth in claim 1 further comprising the step of applying a time gain compensation to adjust each of the signal intensity data points for depth-related attenuation.

13. A method as set forth in claim 1 further comprising the step of smoothing the corrected intensity level of each of said plurality of intensity pixels having a feature gain factor below a predetermined level.

14. A method as set forth in claim 13 wherein the predetermined level below which the corrected intensity level is smoothed is about ten percent of a peak compressed intensity level.

15. A method as set forth in claim 13 wherein the corrected intensity level is smoothed by averaging the corrected intensity level with corrected intensity levels of at least one adjacent intensity pixel.

16. A method as set forth in claim 1 further comprising the step of displaying in a contrasting color the corrected intensity level of each of said plurality of intensity pixels having a feature gain factor above a predetermined level.

17. A method as set forth in claim 16 wherein the predetermined level above which the corrected intensity level is displayed in a contrasting color is about fifty percent of a peak corrected intensity level of said plurality of intensity pixels.

18. A method as set forth in claim 1 wherein said digitized scan line is a first scan line of a plurality of digitized scan lines.

19. A method as set forth in claim 18 wherein said plurality of digitized scan lines consisted of between about 60 scan lines and about 120 scan lines.

20. A method as set forth in claim 18 wherein said plurality of digitized scan lines are arranged in an arc.

21. A method as set forth in claim 20 wherein said arc spans an angle between about 45 degrees and about 90 degrees.

22. A method as set forth in claim 1 wherein said scan line is digitized at a rate equal to about 4 times a center frequency of the ultrasonic energy reflected by structures within the body.

23. A method as set forth in claim 1 wherein the rate at which said scan line is digitized is about thirty megahertz.

24. A method as set forth in claim 1 wherein each of said plurality of linearly arranged signal intensity data points has a length equal to about 25.7 micrometers.

25. A method as set forth in claim 1 wherein each of said plurality of intensity pixels includes about 32 adjacent signal intensity data points.

26. A method for reducing speckle in an ultrasonic image formed from a digitized scan line including a plurality of linearly arranged signal intensity data points obtained from ultrasonic energy reflected by structures within a body, said method comprising the steps of:

dividing the scan line into a plurality of intensity pixels, each of said intensity pixels including at least one data point of said plurality of signal intensity data points;

determining a raw intensity level for each of said plurality of intensity pixels;

selecting a feature detection pixel corresponding to each intensity pixel of said plurality of intensity pixels, each of said feature detection pixels including at least one data point of said plurality of signal intensity data points;

developing a normalized power spectrum for each feature detection pixel;

determining a feature gain factor for each feature detection pixel from the normalized power spectrum thereof;

calculating a corrected intensity level for each of said plurality of intensity pixels by multiplying the raw intensity level for each intensity pixel by the feature gain factor for the corresponding intensity pixel; and

displaying the corrected intensity level of each of said plurality of intensity pixels.

27. A method as set forth in claim 26 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels comprises:

rectifying a signal intensity obtained for each data point within the respective intensity pixel; and

calculating an average of the rectified signal intensities of the data points within the intensity pixel.

28. A method as set forth in claim 27 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels further comprises compressing the calculated average of the rectified signal intensities for the intensity pixel.

29. A method as set forth in claim 28 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels comprises logarithmically compressing the calculated average of the rectified signal intensities for the intensity pixel.

30. A method as set forth in claim 26 wherein the step of determining the raw intensity level for each of said plurality of intensity pixels is repeated over time to provide a digitized intensity level waveform for each of said intensity pixels, and the step of determining the feature gain factor for each pixel of said plurality of intensity pixels comprises:

rectifying the intensity level waveform for each of said feature detection pixels;

performing a Fourier analysis on the rectified intensity level waveform to obtain Fourier coefficient amplitudes for each of the feature detection pixels; and

computing a power spectrum from the Fourier coefficient amplitudes for each of the feature detection pixels.

31. A method as set forth in claim 30 wherein the step of determining the feature gain factor for each pixel of said plurality of intensity pixels comprises:

determining a value of a peak power spectrum for the plurality of feature detection pixels; and

dividing the power spectrum computed for each feature detection pixel by the value of the peak power spectrum for the plurality of feature detection pixels.

32. A method as forth in claim 30 wherein the digitized scan line is a first scan line of a plurality of digitized scan lines, and the step of determining the raw intensity level for each of said plurality of intensity pixels comprises:

calculating an initial intensity level for each of said plurality of intensity pixels; and

averaging the initial intensity level of each intensity pixel and the initial intensity level of an adjacent intensity pixel.

33. A method as set forth in claim 26 wherein each intensity pixel includes about 32 adjacent signal intensity data points.

34. A method as set forth in claim 33 wherein each of feature detection pixel includes about 64 adjacent signal intensity data points.

35. A method as set forth in claim 34 wherein each intensity pixel and the corresponding feature detection pixel share a central pair of signal intensity data points.

36. A method as set forth in claim 26 further comprising the step of applying a time gain compensation to adjust each of the signal intensity data points for depth-related attenuation.

37. A method as set forth in claim 26 further comprising the step of smoothing the corrected intensity level of each of said plurality of intensity pixels having a feature gain factor below a predetermined level.

38. A method as set forth in claim 35 wherein the predetermined level below which the corrected intensity level is smoothed is about ten percent of a peak compressed intensity level.

39. A method as set forth in claim 37 wherein the corrected intensity level is smoothed by averaging the corrected intensity level with corrected intensity levels of at least one adjacent intensity pixel.

40. A method as set forth in claim 26 further comprising the step of displaying in a contrasting color the corrected intensity level of each of said plurality of intensity pixels having a feature gain factor above a predetermined level.

41. A method as set forth in claim 40 wherein the predetermined level above which the corrected intensity level is displayed in a contrasting color is about fifty percent of a peak corrected intensity level of said plurality of intensity pixels.

42. A method as set forth in claim 26 wherein said digitized scan line is a first scan line of a plurality of digitized scan lines.

43. A method as set forth in claim 42 wherein said plurality of digitized scan lines consisted of between about 60 scan lines and about 120 scan lines.

44. A method as set forth in claim 42 wherein said plurality of digitized scan lines are arranged in an arc.

45. A method as set forth in claim 44 wherein said arc spans an angle between about 45 degrees and about 90 degrees.

46. A method as set forth in claim 26 wherein said scan line is digitized at a rate equal to about 4 times a center frequency of the ultrasonic energy reflected by structures within the body.

47. A method as set forth in claim 26 wherein the rate at which said scan line is digitized is about thirty megahertz.

48. A method as set forth in claim 26 wherein each of said plurality of linearly arranged signal intensity data points has a length equal to about 25.7 micrometers.

49. A method as set forth in claim 26 wherein each of said plurality of intensity pixels includes about 32 adjacent signal intensity data points.

50. Apparatus for reducing speckle in an ultrasonic image formed from a digitized scan line including a plurality of linearly arranged signal intensity data points obtained from ultrasonic energy reflected by structures within a body, said apparatus comprising:

a control and processor unit having:

(a) means for dividing the scan line into a plurality of intensity pixels, each of said intensity pixels including at least one data point of said plurality of signal intensity data points;

(b) means for determining a raw intensity level for each of said plurality of intensity pixels;

(c) means for determining a feature gain factor for each pixel of said plurality of intensity pixels;

(d) means for calculating a corrected intensity level for each of said plurality of intensity pixels by multiplying the raw intensity level for each intensity pixel by the feature gain factor for the corresponding intensity pixel; and

a display for displaying the corrected intensity level of each of said plurality of intensity pixels.

51. Apparatus for producing an ultrasonic image comprising:

a transducer for emitting ultrasonic energy into a body and receiving ultrasonic energy reflected by structures in the body as digitized scan lines, each of said lines including a plurality of linearly arranged signal intensity data points;

a control and processing unit operatively connected to the transducer for controlling the transducer and for processing said digitized scan lines by dividing the scan line into a plurality of intensity pixels, each of said intensity pixels including at least one data point of said plurality of signal intensity data points, determining a raw intensity level for each of said plurality of intensity pixels, determining a feature gain factor for each pixel of said plurality of intensity pixels, and calculating a corrected intensity level for each of said plurality of intensity pixels by multiplying the raw intensity level for each intensity pixel by the feature gain factor for the corresponding intensity pixel; and

a display operatively connected to the control and processing unit for displaying the corrected intensity level of each of said plurality of intensity pixels.

52. Apparatus for reducing speckle in an ultrasonic image formed from a digitized scan line including a plurality of linearly arranged signal intensity data points obtained from ultrasonic energy reflected by structures within a body, said apparatus comprising:

a control and processor unit having:

(a) means for dividing the scan line into a plurality of intensity pixels, each of said intensity pixels including at least one data point of said plurality of signal intensity data points;

(b) means for determining a raw intensity level for each of said plurality of intensity pixels;

(c) means for selecting a feature detection pixel corresponding to each intensity pixel of said plurality of intensity pixels, each of said feature detection pixels including at least one data point of said plurality of signal intensity data points;

(d) means for developing a normalized power spectrum for each feature detection pixel;

(e) means for determining a feature gain factor for each feature detection pixel from the normalized power spectrum thereof; and

(f) means for calculating a corrected intensity level for each of said plurality of intensity pixels by multiplying the raw intensity level

for each intensity pixel by the feature gain factor for the corresponding intensity pixel; and

a display for displaying the corrected intensity level of each of said plurality of intensity pixels.

53. Apparatus for producing an ultrasonic image comprising:

a transducer for emitting ultrasonic energy into a body and receiving ultrasonic energy reflected by structures in the body as digitized scan lines, each of said lines including a plurality of linearly arranged signal intensity data points;

a control and processing unit operatively connected to the transducer for controlling the transducer and for processing said digitized scan lines by dividing the scan line into a plurality of intensity pixels, each of said intensity pixels including at least one data point of said plurality of signal intensity data points, determining a raw intensity level for each of said plurality of intensity pixels, selecting a feature detection pixel corresponding to each intensity pixel of said plurality of intensity pixels, each of said feature detection pixels including at least one data point of said plurality of signal intensity data points, developing a normalized power spectrum for each feature detection pixel, determining a feature gain factor for each feature detection pixel from the normalized power spectrum thereof, and calculating a corrected intensity level for each of said plurality of intensity pixels by multiplying the raw intensity level for each intensity pixel by the feature gain factor for the corresponding intensity pixel; and

a display operatively connected to the control and processing unit for displaying the corrected intensity level of each of said plurality of intensity pixels.